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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Heavy Duty Industrial Gear Drives

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Heavy Duty Industrial Gear Drives

ANY machine must be lubricated in accordance with its design and its operating conditions. The heavy duty industrial gear drive is no exception. Provided it has been designed with due regard for the fact that lubricating oil is not a cure-all, it will operate usually with entire satisfaction to the customer, the builder, and the lubricating engineer.

There are certain inherent operating conditions attendant to industrial gears in service; they cannot be eliminated. They will vary widely, but frequently their intensity can be reduced if they are considered when the gear set is designed. Should this fact be overlooked, an overload is imposed upon the lubricating oil used.

The petroleum industry can manufacture to meet this overload within reasonable limits; then the gear set can be serviced economically. Whenever specialty lubricants are required, however, the cost goes up. It begins in the oil refinery with special methods of manufacture. To an extent, it is absorbed at this point. But the subsequent marketing of so-called specialty oils (or lubricants for limited service) is more costly; the customer ultimately must pay a part of this increased overhead.

So the gear designer plans today for the use of conventional gear lubricants to meet conventional operating conditions; they may be straight petroleum in nature, or they may be compounded with a non-corrosive additive to increase the film strength characteristics.

Gear design has progressed through a fascinating transition since the spur gear was first applied to mechanics. When gears were crudely built of wood, with pegs fixed to the rims of wheels to form the teeth, there was but little need for lubrication; both wear and noise were expected. Later when the metal gear became practicable, lubrication was more important. The benefits to be derived therefrom were increased as the art of gear tooth cutting was correlated to mathematics.

So the modern industrial gear developed, with the spur, herringbone, spiral-bevel, hypoid, and worm types predominating in popularity. Their basic function may be any one, or a combination of the following:

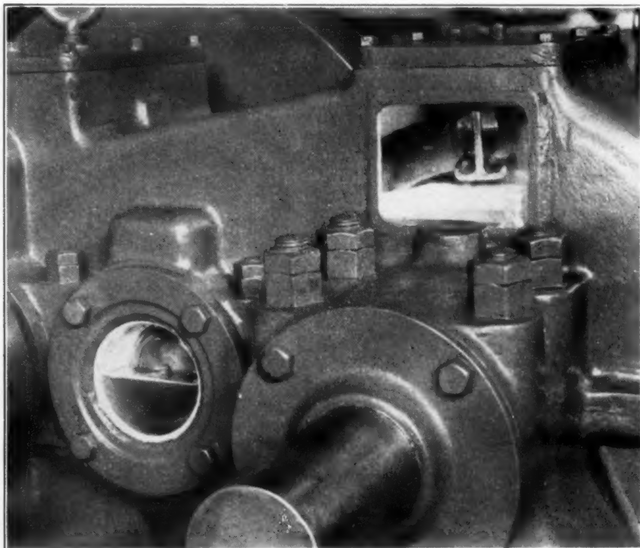
1. To transmit power.
2. To afford a medium for changing speeds.
3. To change the direction of rotation of some machine part.
4. To change the point of application of the power which is being transmitted.

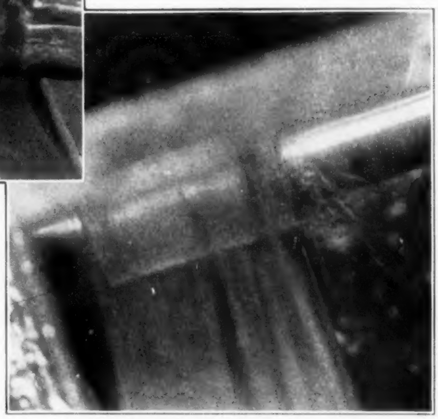
Gears are of distinct advantage wherever it is necessary to eliminate slippage or loss of power as might occur with frictional methods of power transmission, such as friction wheels, belts, or rope drives.

The transmission of motion by means of gears, in general, involves mainly a rolling action between the gear teeth. Certain specific gear types, such as worm gears and hypoids, involve more or less sliding action as well; in fact, sliding action is obtained in all toothed gearing to a certain degree, since the gear tooth surface is essentially a cam. In dealing with non-lubricated surfaces, sliding motion imposes considerably more wear on the surfaces than rolling motion, but in those types of gearing in which the sliding motion is great, and more particularly in the worm gear, the design of the gearing and the materials employed, are se-

lected for their ability to operate with a minimum of friction and wear.

Obviously, lubrication plays a vital part in the operation of such gearing, but although the fact may not have the same general recognition, the lubricant is equally important in those gear types in which the sliding motion is limited, for the reason that such gear types are commonly made of materials selected primarily for strength. This makes them less resistant to wear or galling when sliding together under pressure, which greatly magnifies the importance of even a slight sliding motion.





Courtesy of Lufkin Foundry & Machine Company

Fig. 1—(Above) Ext rior of a Lufkin Gear Box with glass windows to permit inspection of lubrication within; note oil wiper on the side of the main gear. At right is shown a top view of the gears in operation; note their complete coverage by the flood of oil which is developed.

The essence of efficient gear operation is to have the gear teeth roll so smoothly into mesh with such a constant relation in velocity between the mating gears that there will be no vibration set up. This is rather an ideal condition, and in practice, the degree to which this condition is realized is a measure of the merits of the gear design and the skill with which the gearing was made. The most accurately made gearing, however, will be subject to vibration established by the prime mover or the driven machine, and one function of a gear lubricant is to cushion the impacts of the gear teeth upon each other, whether these be due to errors in the profile of the gear teeth, errors in spacing of the gear teeth or mounting of the gears, or to some external source.

In the study and development of gear lubricants, it is essential to know the maximum tooth pressures, the temperature range, and the method of lubrication. The history of the petroleum industry since the beginning of the century scintillates with research of this nature—research which has helped materially in the perfection of gear tooth relationships for the positive and dependable transmission of power.

Effective lubrication results in:

1. Quiet operation with minimum vibration or shock between the teeth.
2. Minimum wear with corresponding increase in the life of the gears.
3. Less wear on all adjacent operating parts which are affected by the rolling of the gears.
4. Maintenance of gears at their designed strength and tooth capacity.

TYPES OF GEARS

Gears are defined according to their design, their principle of operation, and their manner of construction. Industrial gears are usually circular or conical with an axis common to that of the shaft or drum on which they are attached or cut. Those most common to industrial machinery are known as spur, bevel, spiral, spiral-bevel, hypoid, herringbone, helical, internal and worm gearing, according to the manner in which their teeth are cut and the direction in which their motion is to be transmitted. The principle of gearing is also further extended to cover the rack and pinion, a device which includes a flat surface on which gear teeth are cut, to mesh with a worm or spur gear (pinion) to bring about reciprocating motion.

The Spur Design

Spur gears or gears which consist of a cylinder, wheel, or disk on the surface of which are

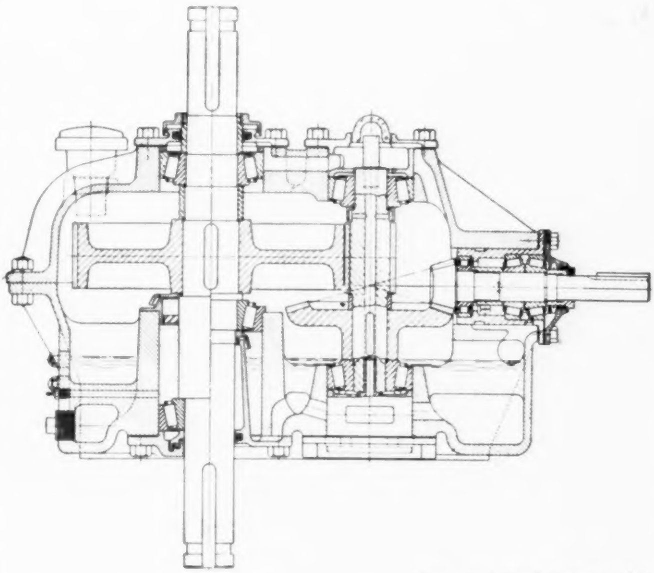
cut parallel teeth, are commonly used to transmit motion from one parallel shaft to another, this motion being either in the opposite or the same direction, according to whether a train of two or more gears are involved. An intermediate spur gear when located between the two main gears will serve to bring about the same direction of motion in the driven gear as is developed by the driver. When three gears are involved as above, the size of the intermediate element has no bearing upon the speed attained by the driven gear; it serves only to reverse the direction of rotation of the latter.

Spur gears are most commonly found on industrial machines, working under ordinary conditions, at moderate speeds and with medium pressures exerted upon the teeth. They may be built either encased or exposed, according to the nature of their service and the extent to which they require guarding, or protection against abrasive matter or dust. Exposed gears may often involve lubrication difficulties. Normally, they will require a lubricant which will adhere tenaciously to the teeth and resist the action of centrifugal force, speed, and temperature changes. Where tooth pressures are not abnormal and the teeth are not subjected to heavy shocks, there is no necessity for the use of a relatively high viscosity lubricant. In fact, if the lubricant is too heavy it will defeat certain of the advantages of lubrication by imposing more or less drag on the gears and increasing their power consumption. As tooth pressures increase, however, the viscosity of the lubricant should be somewhat higher in order to insure that the film on the teeth will be able to resist the cutting and squeezing action of their surfaces, especially when sliding motion takes place. Here we are approaching the condition where a lubricant of increased film strength should be used.

Bevel and Spiral Bevel Gears

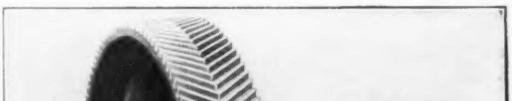
Bevel gears, in turn, are those wherein the teeth are cut on an angular surface, such as would be represented by a truncated cone. They are used for the transmission of motion between shafts whose center lines intersect, or, in other words, form an angle between each other. This is usually a full 90 degree angle inasmuch as the shafts are commonly located at direct right angles with respect to one another; the gears in such cases are known as angle gears. Where two bevel gears are of the same size and their speed ratio remains the same, they are known as mitre gears. Where unequally-sized bevel gears are involved, they are termed angle reduction gears.

Bevel gears under ordinary operation will



Courtesy of The Falk Corporation

Fig. 2—Outline of a Falk double reduction right angle vertical gear set showing provision to guard against leakage of lubricant.

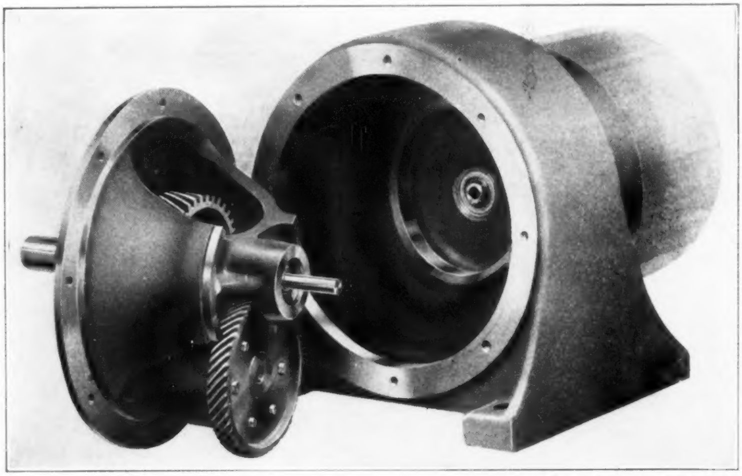


Courtesy of W. A. Jones Foundry & Machine Company

Fig. 3—Exposed view of a Jones triple type herringbone reducer.

differ but little in their lubrication requirements from spur gears.

The spiral-bevel gear is also applicable to non-parallel shafting, when it is termed an angle drive; in appearance it approaches the spiral type of tooth, such as is used on the helical gear.



Courtesy of J. D. Christian Engineers

Fig. 4—Exposed view of the J. D. Christian design. This entire gear unit is a self-contained assembly, so arranged that it can be rotated to any of four positions. In any position there is always adequate lubrication.

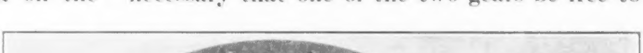
The Helical or Herringbone Gear

The helical gear resembles the spur gear in that the teeth are cut on a cylindrical body, but the helical gear differs from the spur gear in that the teeth are spiraled around the body, rather than formed parallel to the axis of the gear body. The effect of spiraling the teeth in the helical gear is to provide greater smoothness of operation than is normally afforded in a spur gear, for the reason that at some point along the length of the helical gear tooth, contact with the mating gear will always be realized on the center line between the two gears, which is the most favorable condition for uniform motion.

The herringbone gear resembles two helical gears having reversed directions of spiral, placed side by side, so that the teeth come together to form a chevron pattern. In general, helical or herringbone gears are employed with parallel shafts. They can be built to resemble bevel gears, in which case they are usually known as spiral bevel gears, or the helical gear may be employed to connect shafts that are not parallel, but which do not intersect. This latter construction is not frequently employed, as the resulting gears have only point contact between the teeth, and consequently, do not have very high load carrying capacity.

While the advantage of the helical gear over the spur gear is that it favors the maintenance of uniform motion, and so can more easily be made quiet, the helical gear produces an end thrust in the shaft on which it is mounted, that must be taken care of by the shaft bearing. In the herringbone design, the fact that the teeth are spiraled in both directions neutralizes the resulting end thrust, which in many instances is an advantage.

In order that the load on a herringbone gear can be equally distributed between the two angled flanks of the gear tooth, it is necessary that one of the two gears be free to float in the direction of its axis. For this reason, and because the herringbone gear is, in general, more expensive to manufacture than



Courtesy of The Marley Company

Fig. 5—Top view of the Marley spiral-bevel "Geareducer". This unit is designed for bath lubrication, an extra large oil reservoir being available. This allows for cooling and also rest for the oil.

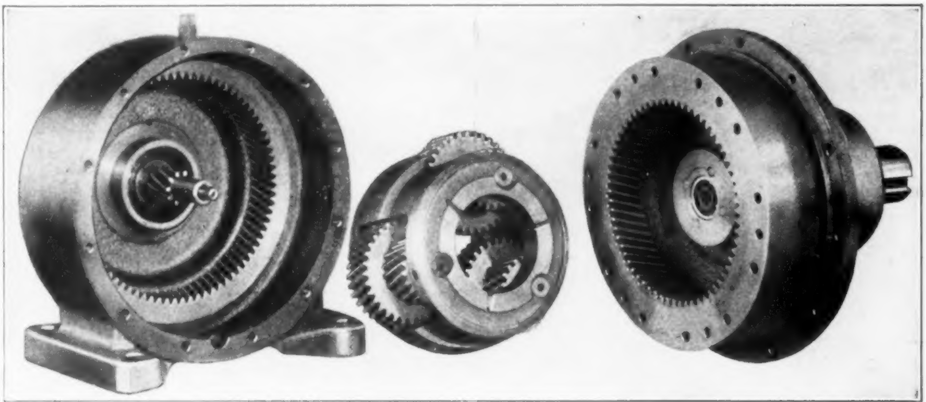
the spur gear, herringbone gearing is generally used in enclosed drives, where fluid lubricants can be employed. For the latter reason, helical gears also are generally encountered in enclosed drives.

The function of the lubricant on helical or herringbone gearing is to reduce friction under both the rolling and sliding motions, and to cushion the gear teeth against vibration. Excessive vibration or rattling in gears of this type often tends to start pitting, particularly along the pitch line. Pitting of this nature is cumulative, to the extent that metallic scale may often be developed and broken off, with a consequent alteration of the tooth profile. For this reason, it is advisable to run such gears in a bath of relatively fluid lubricant; as the speed is increased, the temperature of operation will rise to a certain extent, so the operating viscosity of the lubricant will be reduced.

The Hypoid

In contrast with the conventional spiral-bevel gear where motion is largely of a rolling nature, the hypoid develops a longitudinal sliding motion between the teeth of the pinion and ring gear. This greater sliding action between the teeth of a set of hypoid gears creates a wiping effect which, combined with high tooth pressure, may rupture the lubricating film unless the lubricant is manufactured to develop high load-carrying capacity. Hence, the development of those extreme pressure (E.P.) and hypoid lubricants which have become so well known to the motorist; and the industrial E.P. lubricants for gear service in steel and the allied industries where load conditions comparable to the hypoid prevail.

Industrial gearing need not be of the hypoid type to require an E.P. lubricant. It is more generally of herringbone or spiral design, but built for high speed and overload service. Here comparatively fluid lubricants are used, being circulated to the gear teeth and bearings by pressure, in contrast to automotive service where bath lubrication prevails.



Courtesy of Winfield H. Smith, Inc.

Fig. 6—The WHS differential speed reducer showing planetary gear assembly. Note design of the gear teeth and compactness of the entire assembly.

Annular or Internal Gearing

An annular gear is internal in nature; it has parallel teeth similar to the spur gear, but cut on the inside rim or inner surface of the cylinder or ring. The companion pinion of an annular gear, however, must be a standard spur gear. Internal gear sets are often used for large reductions where the direction of motion may have to be reversed. The main driving element on certain types of tractors is a typical example of the employment of gears of this type. Lubrication of such gearing is similar in principal to spur gearing; therefore, corresponding grades of gear lubricants can be used, especially where exposed operation is being compared.

The Worm Gear

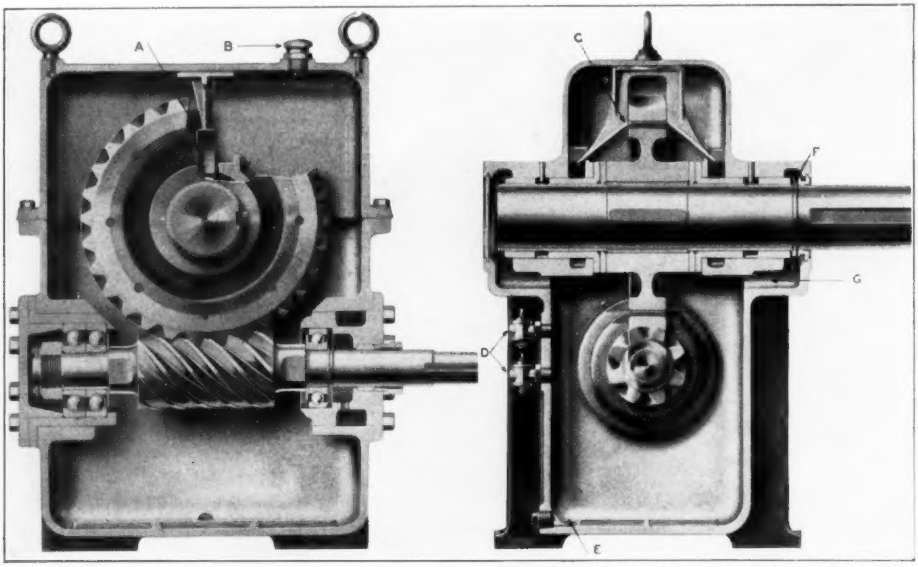
Worm gears are frequently used where a right angled drive is required, or, in effect, where two non-intersecting shafts are located at right angles to each other, but not in the same plane. Parallel shaft drives can be obtained with worm gears by using two pairs of worms and gears. The two members of a worm gear train are known as the worm and the worm wheel, or gear. The worm resembles a screw, although it is really a special form of helical gear, and its teeth are referred to as threads.

The worm is usually made of a hard, wear-resistant steel; the worm wheel, which resembles a helical gear, except that it is throated, or curved on the face to envelope the worm partially, is preferably made of a grade of

bronze having good bearing properties. The worm is normally the driver, and its action on the worm gear is quite similar to the action of a screw on a nut. Due to the wedge-like action of the worm thread on the gear tooth, it is relatively easy to obtain quiet operation with this type of gearing; it also provides a very wide range of speed reductions.

Except where the speeds are very low and the loading relatively light, worm gears are generally enclosed, and bath lubricated. Open worm gears, where used, require a lubricant that will adhere to the teeth, but yet be fairly fluid. Enclosed worm gears, particularly where a hardened steel worm operates with a bronze gear, are usually lubricated with a compounded steam cylinder oil. This rather heavy-bodied oil is necessary in worm gearing, to resist the squeezing-out pressure exerted by the teeth, and to provide the protective film between the teeth that is depended upon to minimize the friction of the sliding motion inherent in worm gearing, and at the same time to cushion the impacts between the teeth resulting from gear inaccuracies, or uneveness of the load being transmitted.

In the average bath lubricated worm gear installation, either the worm or the gear is permitted to dip into the lubricant to the extent of perhaps three or four inches, according to the size and arrangement of the gearing, thus providing a sufficient amount of lubricant on the teeth to afford a protective film, but not in such excess as to cause "drag".



Courtesy of De Laval Steam Turbine Company

Fig. 7—Cutaway details of the De Laval worm reduction gear. Note at "A" and "C" the oil scrapers for gathering oil from the worm wheel to lead it to the wheel shaft bearings and thrust plates; "B" the oil filler plug; "D" the oil cocks to control the level in the gear case; "E" the oil drain; "F" the oil slinger to prevent oil from following the shaft and escaping at the side of the case; and "G" the passage for returning oil to the gear case

GEAR NOISES

W. P. Schmitter of Falk Corporation in his paper presented before the American Gear Manufacturing Association, September 8–10, 1936 has discussed in detail, the disturbances which cause gear noise. He voices the opinion that they must be eliminated at the source; his definition of gear noise is that it "is to a large degree the result of recurrent separation of the contacting teeth."

As a pair of gear teeth must be a loosely coupled mechanism with adequate clearance to allow of normal expansion with increase in temperature, lubrication becomes a prominent factor in so filling this clearance as to cushion the impact effect between the teeth. Yet lubrication, as Mr. Schmitter has warned, may also become a contributing factor to the ultimate noise effect, if excessive impact or splashing within itself should develop. This can be caused by too rapid circulation of a relatively fluid gear lubricant, or carrying the batch level of a heavier product so low that the gear teeth will "slap" into it instead of churning.

Lubrication should not be regarded too loosely as an eliminant for gear noise; it will often reduce the effect which may develop through improper design, installation, or operation, but it cannot eliminate the cause. Granting, however, that the latter oftentimes cannot be corrected, effective lubrication will be very helpful in preventing scuffing or pitting which may develop through continuous and excessive tooth impact. Ultimately, these

defects may be observed, however, even with the best of lubrication; when and if this may occur, it is no fault of the lubricant, unless application of the latter has been neglected.

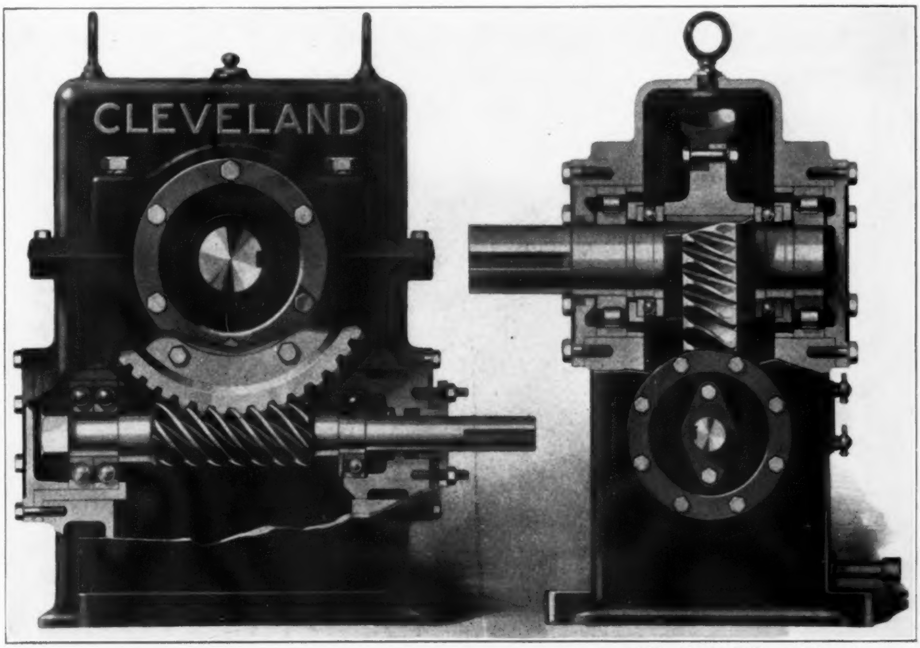
SELECTION OF THE LUBRICANT

The ideal gear lubricant must possess certain very definite properties, such as:

1. Sufficient adhesiveness to insure that it will remain on the teeth and resist the action of centrifugal force.
2. Such a viscosity as to ably resist the effects of heat, and form a suitable film, regardless of tooth pressures or temperatures.
3. No tendency to harden or become brittle and chip off in event of exposure to abnormally low temperatures.
4. Sufficient "oiliness" or lubricating ability to reduce to a minimum the friction which occurs between the teeth.
5. Sufficiently low cost to enable it to be purchased and applied at a reasonable expenditure in comparison with the value of the service rendered.

to varying directions of load application. Were rolling contact alone involved, the intensity of such a load momentarily on any part of a gear tooth could be disregarded. But sliding motion is practically always present as well; this explains the abnormal wear that occurs where gears are not properly lubricated, or, in other words, where the tooth surfaces are subjected to a continual grinding action.

There are any number of gear lubricants on the market today which have been designed to meet the requirements stated above. They will vary all the way from fluid mineral oils such as steam cylinder stocks, to intricate grease compounds, some of which may contain "fillers". The latter serve but one purpose in a lubricant: to increase the viscosity and weight. They possess no appreciable lubricating value. Therefore, they should not be used as they are deceiving, and may lead an uninformed user to feel that his lubricant is suitable, when, in reality, it is affording comparatively poor protection against wear. The necessary adhesive characteristics may also be relatively low. As a result, when used under high-speed

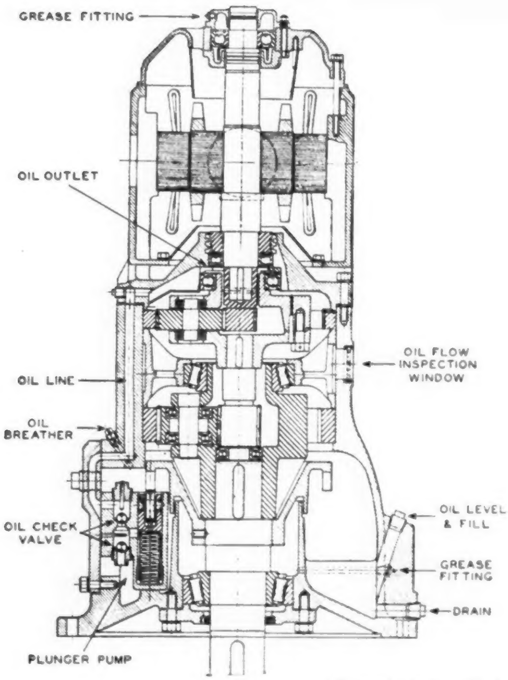


Courtesy of The Cleveland Worm & Gear Company

Fig. 8—Side and end views in detail of a standard Cleveland Type AH worm gear unit. Note use of ball and roller bearings throughout. Cartridge type oil seals prevent leakage of oil around the low speed shaft.

In any gear installation the pressures usually encountered will be high; they may be especially severe on the bearing surfaces, inasmuch as a relatively small area of contact is involved. The pressure developed by this contact is constantly shifting as the teeth are subjected

conditions, or wherever the gears may come into contact with water, acids, alkalis, or chemical fumes, the gear teeth may lose their protective film of lubricant, due either to its being thrown off by centrifugal force, or washed from the wearing surfaces.



Courtesy of Philadelphia Gear Works

Fig. 9—Lubrication details of the Philadelphia Gear Works vertical double reduction motor-gear unit. Note the dry well construction of the slow speed shaft extension; oil is kept out of this well by an umbrella shield.

ways appear to be carrying sufficient lubricant, yet this will be present only after the pressure between teeth has been relieved. Immediately adjacent teeth engage, metal-to-metal contact may take place with resultant wear and abrasion, due to this lubricant's being unable to withstand the pressures. Oftentimes, this can be proven by the presence of metallic particles when the used grease is subjected to laboratory analysis.

CONDITIONS OF OPERATION

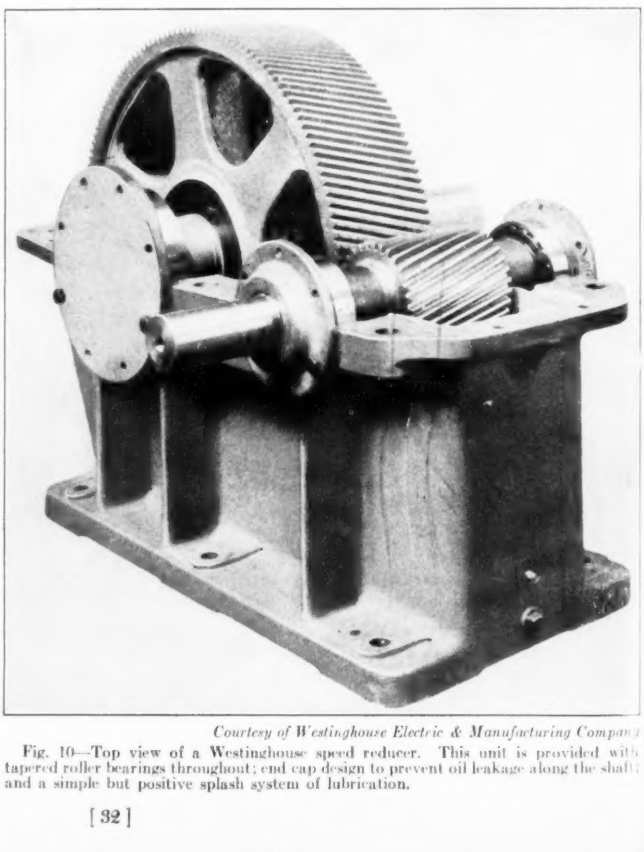
Gear lubricants may be exposed to adverse operating conditions, according to the extent to which the gears are housed; for example:

1. The presence of considerable dust in the air as a result of material used, as in the steel or rubber industry, may cause heavier gear lubricants to become veritable grinding compounds.
2. The heavy pressures that are customary on certain types of steel mill pinions, rubber plant mixers, or cement mill kilns, may squeeze out ordinary lubricants, permitting actual tooth contact.

Where dust must be counteracted and complete housing is not practicable, a gear lubricant must be light enough to absorb a considerable amount of dust before it tends to

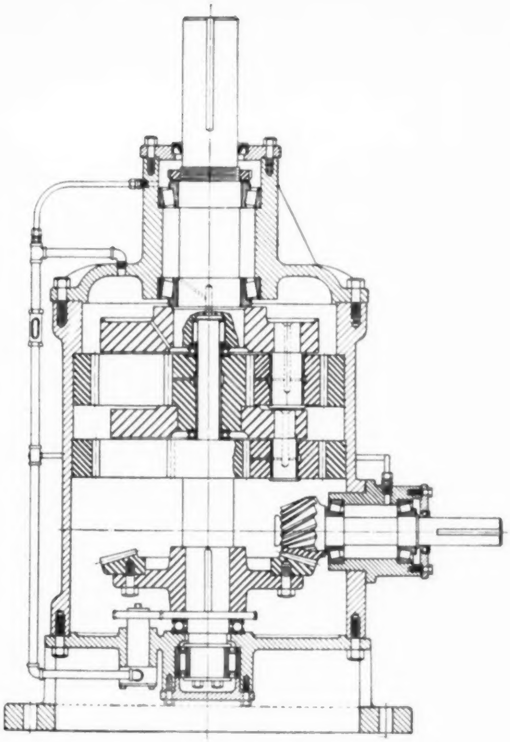
Where greases are being considered, it is important to remember that from a lubricating point of view they will only be as good as the mineral oil which has been used in their makeup. The soap constituent serves somewhat as a sponge: to carry the oil and retain it in a more or less solid mass, according to the percentages of soap and oil involved. As soap has but little lubricating value, it is usually best to obtain the desired viscosity directly from the mineral oil itself, rather than by using an artificial thickener.

One of the primary faults with a light oil grease, in turn, is that it will often function, apparently quite satisfactorily, yet the film created upon the gear teeth will be entirely inadequate to resist the squeezing-out action which is developed. The reason is that the tips of the teeth often exert a so-called "smearing" action on the sides of the adjacent teeth when rolling out of mesh, picking up a certain amount of lubricant which has been forced down between them. As a result, the teeth will al-



Courtesy of Westinghouse Electric & Manufacturing Company

Fig. 10—Top view of a Westinghouse speed reducer. This unit is provided with tapered roller bearings throughout; end cap design to prevent oil leakage along the shaft; and a simple but positive splash system of lubrication.



Courtesy of D. O. James Manufacturing Company

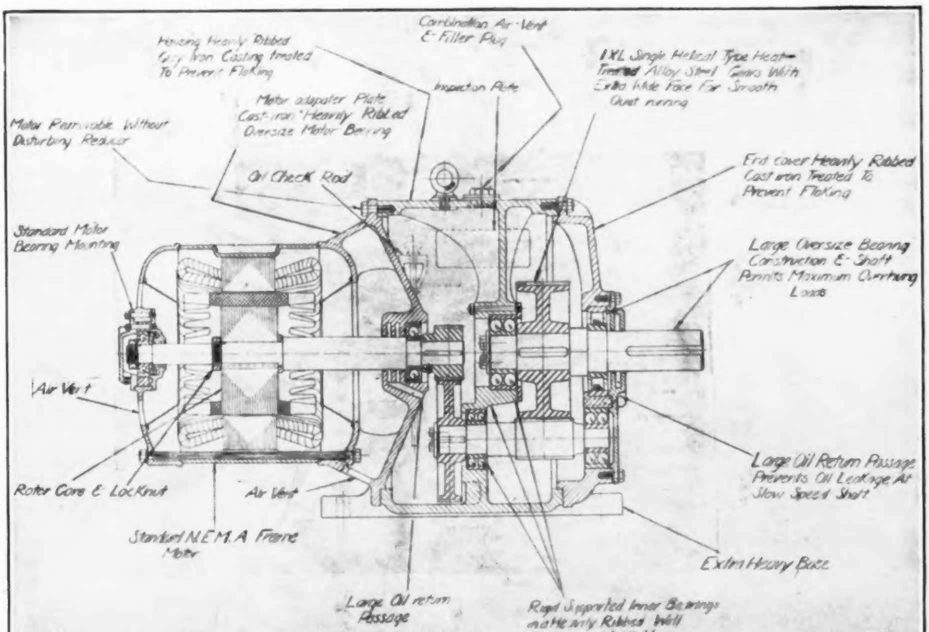
Fig. 11—Section of a James vertical drive right angle speed reducer. Lubrication is maintained by a positive action gear driven oil pump, with means for oil circulation as shown. Note extensive use of ball and roller bearings, and sealed nature of the entire assembly.

roll up into balls and throw off; at the same time, it must be heavy enough to withstand the tooth pressures during the intervals between application or re-lubrication. The frequence of re-lubrication of exposed gears depends entirely upon the service conditions. They must never run dry, nor, in turn, should they be over-lubricated; otherwise, a sloppy condition will prevail. Experience will dictate the proper viscosity, just as it will the best method of application. A grade suited to clean operation may not maintain an efficient lubricating film under dirty conditions.

Where heavy bearing pressures prevail, these, in turn, may be transmitted to the gear teeth to some extent. Sometimes adjusting screws are employed to regulate the pressure to suit the work; widely varying duty may, therefore, be demanded of the reduction and driving gears. Where slower speeds are customary, the possibility of overheating or throwing of the lubricant is reduced; yet wear may be appreciable if a proper film does not coat the teeth completely.

To further appreciate the extent to which such conditions may affect the performance of a gear lubricant, it is interesting to note the several successive reactions to which the latter will be subjected. There are three distinct phases involved, viz.:

1. When the point of the gear tooth comes

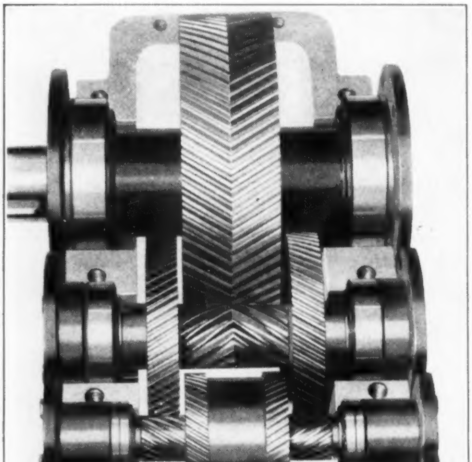


Courtesy of Foote Bros. Gear and Machine Corporation

Fig. 12—Section of the Foote IXL unit type powered gear set showing certain features pertinent to the lubricating system, also bearings and methods of sealing to prevent oil leakage.

into contact with the root of the companion pinion tooth.

2. Where both teeth are in contact adjacent to their pitch lines.



Courtesy of The Horsburgh & Scott Company

Fig. 13—Top view of a Horsburgh & Scott triple reduction herring bone speed reducer. Lubrication is accomplished by splash, the gears and bearings being continually supplied with fresh cool oil.

3. Where the reverse of the first takes place as the teeth pass out of mesh.

Sliding motion is most likely to occur when the teeth first come into contact and as they become disengaged, the points of the respective elements developing a more or less scraping action on the sides of the adjacent teeth. Both wiping action and squeezing will be apt to occur at these times. As the teeth become more and more engaged, however, sliding contact is replaced by rolling contact; in other words, the ideal operating condition for gearing is approached. Wiping or scraping off of the lubricant is, therefore, practically eliminated, but the squeezing out action still is possible, especially as maximum bearing pressures are encountered during the time the teeth are so engaged. Wear will occur more rapidly at the points and roots of the teeth due to the sliding friction involved; whereas, the intermediate tooth surfaces adjacent to the pitch line being subjected to rolling action, will resist wear more effectively.

METHODS OF GEAR LUBRICATION

Gear lubricants must be applied according to service involved. We are most generally familiar with automotive practice where the gears in the transmission and rear end are bath lubricated. Contrast this with industrial production: viz., the gears which drive the rolls on certain rubber machines which may be either bath or hand lubricated; the gearing on excavating machinery which is largely hand oiled; and turbine reduction gears which are lubricated by force-feed. This latter method of

Courtesy of W. A. Jones Foundry & Machine Company

Fig. 14—Sectional view of a Jones herringbone reducer showing gear and bearing arrangement. Symmetry and balance are important features in herringbone assembly, as they permit the use of standard type bearings of uniform size on each shaft.

lubrication is also now widely applied to enclosed type steel mill reduction gear sets.

So a wide variety of conditions exist, each of which may require special consideration accord-

Courtesy of The Horsburgh & Scott Company

Fig. 15—An assembly of Horsburgh & Scott double reduction worm gears showing worm and gear design, also applicability of anti-friction bearings.

ing to the design of the machine, the size and number of the gears and the products being handled. Certain of the latter will be of a perishable nature such as foodstuffs, paper and textiles. Gearing on the attendant machinery must be so lubricated that there will be practically no chance of the gear lubricant splashing, dripping or being thrown onto these products. Others require little or no consideration of this nature and oftentimes, in such cases, even waste oils are slopped all over the machinery due to careless lubrication of the gears.

Analysis of industrial machinery presents five distinct conditions pertinent to gear lubrication:

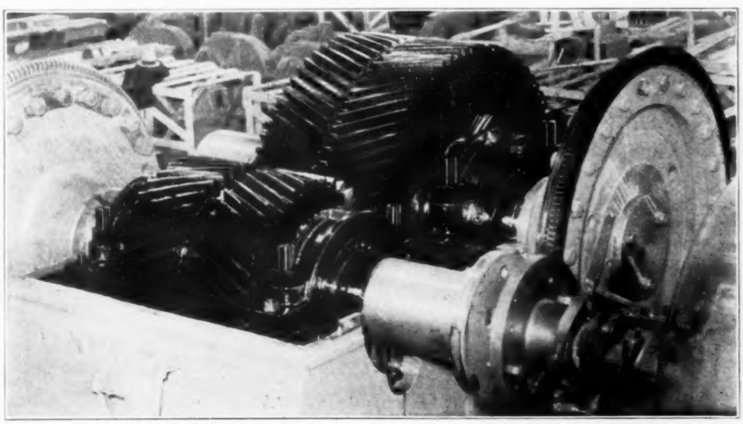
1. Where the gears are enclosed in a suitable casing, out of contact with the bearing lubricant, running either in a bath of oil or being lubricated by force-feed.
2. Where gears run in an enclosed case, the gear lubricant at the same time serving the bearings, as is true in many reduction gear installations, viz., the worm gear set.
3. Where gears are entirely exposed, the lubricant being applied by hand.
4. Where the gears run exposed, but with their lower portions encased so that bath lubrication is possible.
5. Where gears are open, and exposed to such dirty conditions as to render practically any lubrication ineffectual.

Where and when to use any specific grade of lubricant is, therefore, oftentimes quite a problem. It is disconcerting to attempt to heed all the modern arguments in favor of industrial plant efficiency, and at the same time have a noisy set of gears which may refuse to function properly with ordinary methods of lubrication. Such conditions are not entirely hopeless, even though perhaps the air may be filled with dust, or the gears subjected to hot water or acids, etc. The petroleum industry has solved this problem by developing specialty lubricants refined so as to stick and lubricate even when totally submerged in practically boiling water.

There are available similar lubricants for pressure conditions as already mentioned. These along with the wide range of straight mineral gear lubricants will serve virtually any condition of operation or means of application. It only requires judicious study of these conditions along with the physical characteristics of the lubricants.

This brings us to means of application—likewise, the importance of cleanliness. Where pans are furnished for bath lubrication they should be cleaned out at regular intervals, since any dust that may have gained entry will destroy the adhesiveness of the gear lubricant, tending to form a solid pasty mass which the gears can not pick up.

Where the gears dip in a bath of lubricant,



Courtesy of The Falk Corporation

Fig. 16—Exposed view of a large steel rolling mill drive showing complete coverage developed by use of a suitable lubricant.

this bath should be just deep enough so that the lowest teeth are just covered. This will give ample lubrication and keep the consumption of the lubricant at a minimum.

When the lubricant is applied by hand, it

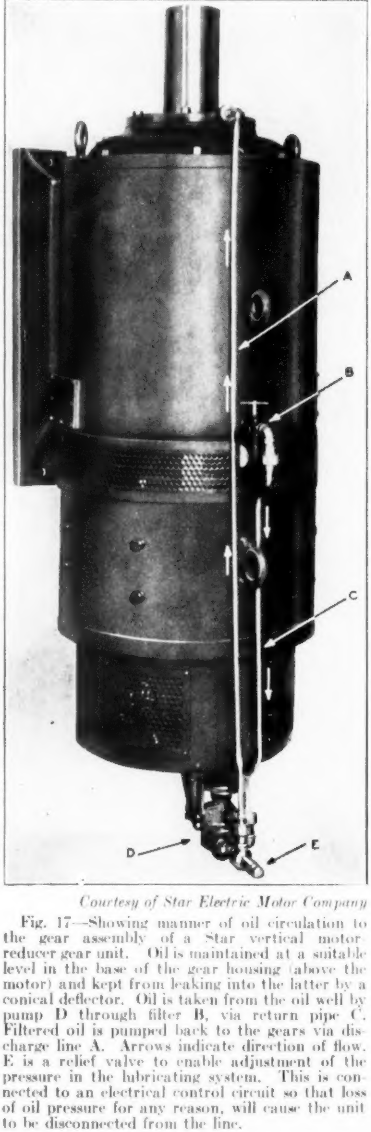
should be slightly heated to reduce it to the consistency desired, and painted on with a short brush, or poured on from a dipper as the gears are slowly revolved towards each other. Pouring the lubricant on in a fine stream is easiest, most economical and most effective.

Gear lubricants should be applied to open gearing relatively frequently and in small quantities, rather than in considerable volume and at longer intervals. Thus there will be less danger of gobs of lubricant being thrown off by centrifugal force, to possibly contaminate the products passing through the machine.

In case the lubricant becomes laden with foreign material at the root of the gears or between the gear and shield and begins to cake, this cake often can be softened and removed by the use of kerosine or some petroleum solvent.

FUNCTION OF THE LUBRICATING ENGINEER

The lubricating engineer must deal with equipment as it stands, hence he must develop the best practices possible to meet and serve existing conditions. To a certain extent recommendations are possible for alteration in bearing design, gear and bearing protection against contamination, for the use of oil-tight sheet metal housings over exposed gears and for preservation and reclamation of applied lubricants, etc., but to be effective any such recommendation must be carried out by the mechanical organization of the plant; it requires close attention and careful experimentation. The ultimate purpose of course is to reduce the cost of lubrication, to lessen the burden which is borne by the lubricant and to increase gear life.



Courtesy of Star Electric Motor Company

Fig. 17—Showing manner of oil circulation to the gear assembly of a Star vertical motor-reducer gear unit. Oil is maintained at a suitable level in the base of the gear housing (above the motor) and kept from leaking into the latter by a conical deflector. Oil is taken from the oil well by pump D through filter B, via return pipe C. Filtered oil is pumped back to the gears via discharge line A. Arrows indicate direction of flow. E is a relief valve to enable adjustment of the pressure in the lubricating system. This is connected to an electrical control circuit so that loss of oil pressure for any reason, will cause the unit to be disconnected from the line.

This requires also that the lubricating engineer have an intimate knowledge of the basic characteristics of the conventional gear lubricants at his disposal. He must be aware of the degree to which their physical characteristics may change under operating conditions, especially where operating temperatures may vary comparatively widely. Gear lubricants are identified by their viscosity or relative fluidity. This characteristic is normally measured at 210 degrees Fahr., due to the relatively heavy nature of these particular types of lubricants. Other characteristics, however, such as the pour test must also be considered, especially where operating conditions call for the more fluid types of gear lubricants which must serve not only the gearing, but also the attendant gear shaft bearings. Many times comparatively low temperatures will be involved. As a result knowledge and ability to evaluate the significance of the pour test is very helpful.

It is also beneficial for the lubricating engineer to have thorough knowledge of the means of lubrication which have been provided by the gear manufacturer for the installations with which the former is concerned. Obviously, pressure circulating systems must be supplied with lower viscosity lubricants than gearing which is exposed and expected to be lubricated by hand application of the lubricating material.

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